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ABSTRACT

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Adaptive Instructional Models:

Diagnostic and Prescriptive

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University of Minnesota

Symposium

Theoretical Approaches to Adaptive Instruction

Session # 32.01

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Abstract

Presented are variables and conditions for design of a computer-based adaptive instructional system. The design strategy uses Bayes' theory of conditional probability to determine an instructional sequence according to individual student characteristics and needs. The adaptive strategy uses prior estimates based on student pretask and on-task performance in an algorithm that makes selections of instructional sequence from a table of generated values. The computer system provides a dynamic environment which updates each students on-task learning progress and modifies the instructional sequence accordingly. The purpose of this adaptive strategy is to improve the effectiveness of the learning environment, resulting in reductions in student learning time while improving task acquisition.

Adaptive Instructional Models: Diagnostic and Prescriptive

Robert D. Tennyson

University of Minnesota

My presentation today will focus on the design of a computer-based, adaptive instructional model. Work on this model began several years ago in relation to my research on design strategies for teaching concepts. The design strategies derived from this research include the following: (a) presentation of the defining statement in terms of critical attributes; (b) presentation of examples which show a divergence of the variable attributes; (c) presentation of examples and nonexamples which show a matching of variable attributes; and (d) presentation of instances with various difficulty ratings. However, a design strategy for determining number of instances and sequence of instances in the learning of coordinate concepts was missing. Thus, we directed our efforts towards the study of variables which would provide a procedure for selecting the appropriate number of instances and sequence according to individual student characteristics and needs. (R. Tennyson & Rothen, 1977; C. Tennyson, R. Tennyson, & Rothen, in press.)

Following current practices we begin with the notion that if development in a wide range of persons is to be facilitated, a wide range of environments suited to the optimal development of each individual student must be offered. Instructional units covering available content elements in different sequences would be adapted to differences among students. This design strategy prescribes one type of instructional sequence for a student of certain characteristics, while another learner of differing characteristics would receive

a different form of instruction. Of course, this instructional design strategy is termed aptitude treatment interaction (ATI). Variations of the ATI label have been introduced by researchers (expressing individual differences) in attempts to clarify more precise methods of adjusting the instructional stimuli by alternative measures of student characteristics. For example, Tobias (1976) found that the student's prior familiarity with the subject matter seemed a better variable for adjusting instruction than generalized student characteristics.

Our review of the literature indicated that these pretask methods of adaptive instruction are elusive as predictor variables in selecting appropriate instructional stimuli. Several questions were raised in regards to those studies: (a) Can instructional methods be designed to rely exclusively on one set of abilities? (b) What is the temporal consistency of the abilities required by the task? (c) Do the abilities generalize from one curricular area to another? (d) Is it practical to prepare completely alternative instructional treatments? In contrast to this line of adaptive instruction, we (Rothen & Tennyson, in press) proposed that instead of seeking ATIs (or their equivalent) to assign individual students to different macro-treatments, we would use the ATI information to revise an optimal treatment. Then, after the effectiveness of a single best treatment has been maximized, micro-treatment variables could be applied adaptively within the instructional program. The adaptive instructional strategy we proposed is characterized as an iterative algorithmic model with the capability to decide amount and sequence of instruction in reference to student needs in learning concepts at a given level of criterion.

The functional operation of our adaptive instructional strategy is related to guidelines described by Novick and Lewis (Note 1) for determining the minimal length of posttests adequate to provide sufficient information regarding the learner's degree of mastery of the behavior being tested. Novick and Lewis' precedure involves first a pretest on a set of objectives, from which initial prior estimates of a student's ability per objective are combined in a Bayesian manner with information accumulated from previous students to generate posterior estimates (using the Beta distribution) of the student's probability of mastery of each objective. This procedure generates a table of values for different test lengths per objective and selects an appropriate number of test items from this table that seem adequate to predict mastery of each objective. Modifications to this standard Novick and Lewis (Note 1) model are made in this proposed adaptive instructional strategy such that a definite rule or algorithm selects an instructional prescription from the table of generated values. In addition, this prescription is updated according to individual student on-task learning performance.

Model Description

To conclude my presentation today, I will present an overview of the model.

Initially an estimate of the student's ability based on prior knowledge is made. The Beta distribution is used to characterize this information in probabilistic terms. This involves making an initial estimate of the probability that the student is already at or above a given criterion level for the objective being taught by administering a pretest and comparing the score to information collected from previous students. The procedure described by

Novick, Lewis and Jackson (Note 2) in the selection of a particular Beta distribution to characterize prior beliefs is used here. Novick and Lewis (Note 1) suggest using a prior distribution ($\underline{P}$) which assigns a probability slightly greater than .5 to the region above the criterion level.

An additional parameter for the algorithm is the setting of a criterion level (π_0) for the objective. To decide on a student's attainment of mastery, it is necessary to select a minimum acceptance probability that a student's true level (π) exceeds or is equal to the criterion. For a test of length $\underline{n}$ with a student's score of $\underline{x}$ a value of π_0 must be selected such that the probability $(\pi \geq \pi_0 \mid x,n) \geq .5$. This is equivalent to at least a 50% certainty that the student's level of functioning is above π_0.

The loss ratio, $\underline{R}$, is defined as the disutilities associated with a false advance to a false retain decision. The loss ratio, $\underline{R}$, refers to the relative losses associated with advancing a learner whose true level of functioning is below π and retaining a learner whose true level exceeds π_0. The decision rule for this algorithm is to match the posterior odds to the loss ratio. If a loss ratio of 2 to 1 is chosen, a probability of 2/(2+1) provides matching odds of 2/3 to 1/3 above criterion to below criterion for the posterior distribution.

To summarize at this point, three kinds of information must be established prior to the initiation of the adaptive strategy to the instruction. First, prior knowledge of the student's true level of functioning must be translated into a prior probability distribution. Second, a criterion level for the objective being taught must be established. This value generally is between .70 and .85. Finally, the relative losses associated with the two types of

advancement retention errors must be decided upon; this value can range from 1/1 to 3/1.

Specification of the parameters $\underline{P}$, $\underline{R}$ and π_o affect an instructional prescription's minimum necessary instruction length. As the prior distribution ($\underline{P}$) assigns a greater certainty that the student's true level of functioning is above the criterion level, instruction length decreases. Large loss ratios increase the length of the instruction to allow the possibility of high posterior probability of mastery. If the criterion level approaches 1 the instructional length is increased so as to provide adequate information about a student's level of functioning in the interval of the criterion.

From the above definitions of a prior distribution, criterion level, and loss ratio, a particular instructional prescription is specified based on a student's operating level. The manner in which the present strategy operates to determine this level is as follows: prior to administering the pretest, the loss ratio is adjusted on the basis of a premeasure score. A high score on the premeasure test is used to adjust the ratio so that the disutilities associated with the error of a false retain is decreased relative to the error of a false advancement. A prior distribution on the basis of a pretest score is established by comparison with historical data for that particular objective. An instructional length specification is then made taking into account the loss ratio and criterion level. The student is then given selected instructional materials of the appropriate amount. These materials are used to establish the operating level for that student. The operating level is updated with each on-task response activity and is used to generate the posterior distribution. If the learner's updated instructional length specification,

based on a matching of the posterior odds with the loss ratio, is less than or equal to the prescription already received, he or she is judged to have correctly mastered the objective and no further instruction is given. The student is then passed to the posttest. If his or her operating level is below that generated from the posterior distribution, his or her posterior distribution is used as a prior distribution with the same parameters for the criterion level and loss ratio as before. A new instructional prescription is then generated. This procedure is applied iteratively until either the student is judged to have mastered the objective or the instructional materials pool is exhausted.

Conclusion

The use of Bayes' theroem in this instructional form is an extension of current Bayesian applications in testing environments (Novick, 1970). For the instructional strategy presented here, the adaptive Bayesian model calculates the probability of the beta distribution from pretask and on-task data sources. First, a loss ratio is calculated as a function of student performance on a premeasure of aptitude. The second data source (pretest performance) forms a continuous beta distribution table from which the initial instructional sequence is formed. The probability resulting from these data sources is further adjusted by individual student on-task learning performance. Also, the beta distribution, which is established for each parameter from formative evaluation data, can be adjusted as increasing numbers of students participate in the instruction. Thus, the extension of this theorem into a dynamic (and computer-based) model for control of an adaptive instructional strategy forms the basis of the model presented in this paper.

Reference Notes

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